Space Technology Research Grants

# Assessing the Feasibility of Using Co-electrolysis to Concurrently Convert Carbon Dioxide and Water into Methane and Oxygen for Propellant and Life Support on Mars

Completed Technology Project (2016 - 2020)

## Project Introduction

By using co-electrolysis with task-specific ionic liquids (TSILs), water from Martian regolith and carbon dioxide from the Martian atmosphere may be simultaneously electrolyzed in an electrochemical cell, producing methane and oxygen in a single process vessel. The following objectives and methods will be undertaken to advance the technology for future crewed missions to Mars. Objective 1 will identify candidate TSILs and electrodes for the cathode compartment of the electrochemical cell. To achieve this, a literature review of potential ionic liquids and cathode materials will be performed in order to identify those suitable for this technology. The next step will be to experimentally verify that they possess desirable characteristics and address knowledge gaps from the literature review. Objective 2 will then evaluate TSILs and electrodes from Objective 1 by characterizing their reaction kinetics, adsorbed species, and intermediates. Rotating disk and rotating ring-disk electrode experiments will be used to study the reduction process of carbon dioxide to methane. The results of these tests will be collectively analyzed to identify and select cathodes and TSILs most conducive to methane production. Objective 3 will focus on designing and fabricating a benchtop-scale electrochemical cell in order to enable the evaluation of selected cathodes and TSILs in a laboratory environment. Objective 4 will characterize the performance of the electrochemical cell with each TSIL and electrode over a range of operating conditions. Candidate components selected at the conclusion of Objective 2 will be integrated into the test article from Objective 3 to parametrically assess the technology on a bench-top scale. The goal is to prove that methane can be selectively produced in relevant operational environments. Objective 5 will assess integrated system-level parameters. The specifications of promising test units, including methane and oxygen production rates, mass, volume and power, will be extrapolated to relevant scales for human spaceflight to enable comparison to functionally similar systems. This research effort is aimed at advancing the technology readiness level of co-electrolysis with TSILs from 2 to 4 by proving the concept of the technology and validating a low-fidelity cell. This will position the technology for further refinement and integration into In-Situ Resource Utilization (ISRU) systems. If an ionic liquid can be identified and implemented in a properly designed electrochemical cell, co-electrolysis should reduce the cost, complexity and risk of crewed Mars missions by simplifying oxygen and methane production to a single chemical step. In fact, an ISRU architecture with this technology would require fewer major processes and components, approximately 50% less mass, and 25% less power than the conventional Sabatier/water electrolysis paradigm for propellant and oxygen production. Acknowledging these advantages and the potential for the technology, NASA calls for the development of co-electrolysis with TSILs in its roadmap for Human Exploration Destination Systems.


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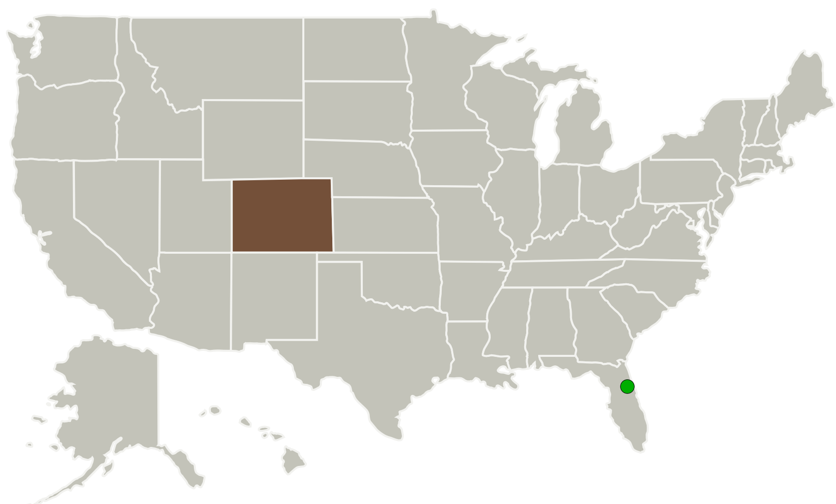
## Anticipated Benefits

If an ionic liquid can be identified and implemented in a properly designed electrochemical cell, co-electrolysis should reduce the cost, complexity and risk of crewed Mars missions by simplifying oxygen and methane production to a single chemical step. In fact, an ISRU architecture with this technology would require fewer major processes and components, approximately 50% less mass, and 25% less power than the conventional Sabatier/water electrolysis paradigm for propellant and oxygen production. Acknowledging these advantages and the potential for the technology, NASA calls for the development of co-electrolysis with TSILs in its roadmap for Human Exploration Destination Systems.

## Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| University of Colorado Boulder | Lead Organization | Academia | Boulder, Colorado |
| Kennedy Space Center(KSC) | Supporting Organization | NASA Center | Kennedy Space Center, Florida |

## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Organization:**

University of Colorado Boulder

**Responsible Program:**

Space Technology Research Grants

## Project Management

**Program Director:**

Claudia M Meyer

**Program Manager:**

Hung D Nguyen

**Principal Investigator:**

David Klaus

**Co-Investigator:**

Michael A Lotto

**Primary U.S. Work Locations**

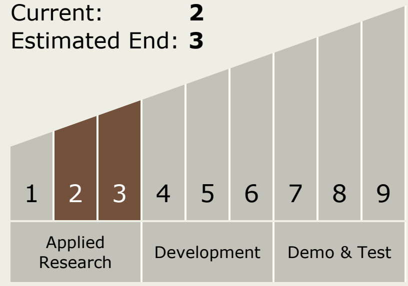
Colorado

**Project Website:**

https://www.nasa.gov/strg#.VQb6T0jJzyE

## Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**




## Technology Areas

**Primary:**

- TX07 Exploration Destination Systems
  - └ TX07.1 In-Situ Resource Utilization
    - └ TX07.1.3 Resource Processing for Production of Mission Consumables

## Target Destination

The Moon